

SEDIMENT CHEMISTRY ASSOCIATED WITH
NATIVE AND NON-NATIVE
EMERGENT MACROPHYTES OF THE
HUDSON RIVER MARSH ECOSYSTEM

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Abstract

Wetland vegetation can influence nutrient cycling through several processes including direct assimilation into plant tissues and indirect effects on sediment hydrology or oxygenation. In tidal freshwater marshes of the Hudson River, *Typha angustifolia* represents the baseline condition while coverage by *Lythrum salicaria* and *Phragmites australis* has increased greatly over the past twenty years. Prior to any attempts at restoration of historical coverage, we wanted to describe the current relationship between these plants and sediment nutrient pools. Extant stands (n=3 of each) of *T. angustifolia*, *L. salicaria* and *P. australis* were sampled with porewater equilibrators in spring and summer of 1995 to measure porewater ammonium, nitrate, and phosphate. Porewater pools of phosphate were significantly lower ($p < 0.05$) in stands of *L. salicaria* with concentrations only half those measured in stands of *P. australis* and *T. angustifolia*. Nitrate was undetectable in sediments associated with all three plant communities and there was depletion of porewater ammonium. Porewater ammonium at the time of peak plant standing crop was highest in *P. australis* beds (0.88 ± 0.19 mg/L) and lowest in stands of *L. salicaria* (0.15 ± 0.02 mg/L). Marsh management practices intended to shift the relative vegetation coverage towards native and non-invasive species should consider the subtle but ecologically significant effects on nutrient cycling.

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Introduction

Wetlands occur at the ecotone between terrestrial and aquatic systems. Their physical and hydrologic characteristics, high biological productivity, and diversity make them important in regulating material fluxes from upland ecosystems and in providing valuable habitats for many animals (Johnston 1993). The composition of vegetative communities is likely to play a large role in the processes affecting nutrient transfers and overall habitat quality (Howes et al. 1986). Removal of exotic or invasive vegetation is a primary technique for wetland restoration. Prior to any attempts at restoration of historical coverage, we wanted to describe the current sediment nutrient pools associated with native and non-native plants of the Hudson River marsh ecosystem.

Emergent macrophytes (aquatic plants) have major effects on production and biogeochemical cycles in fresh water because they occupy key interfaces in river ecosystems. Most macrophytes are rooted, and constitute a living link between sediment and overlying water (Barcko et al. 1991). Root aeration of the sediment is one of the primary adaptations of wetland macrophytes to overcome anaerobic conditions associated with flooded soils (Sifton 1945, Iversen 1949, Armstrong 1979). The formation of aerenchyma tissue improves the internal movement of oxygen to the root apex and is effective in maintaining the energy status of cells at appreciable distances from the shoot (Drew et al. 1985). Furthermore, release of oxygen by plants with aerenchyma may be a way to counteract the toxic effects of reduced minerals (Laanbroek 1990). Aerenchyma tissue in wetland macrophytes not only reduces the amount of respiring tissue relative to root volume, but also facilitates oxygen diffusion to the rhizosphere thereby increasing the oxidation-reduction potential of the sediment (Williams

and Barber 1961, Luxmoore et al. 1970; Armstrong 1972; Mendelsohn and Postek 1982).

Rhizosphere oxidation has important biogeochemical consequences. Redox

potential is a major factor controlling availability of many nutrients in sediments; thus the extension of oxidizing conditions to deeper levels in sediments may affect nutrient availability (Jaynes and Carpenter 1980). Rooted aquatic macrophytes rely primarily on sediment as a source of nitrogen and phosphorus (Nichols and Keeney 1976; Barko and Smart 1980). Availability of these and other sediment nutrients to aquatic macrophytes depends on physical and chemical characteristics of the sediment and microbial activity in the rhizosphere (Barko and Smart 1986; Barko et al. 1986). Rhizosphere oxidation by vascular macrophytes could decrease P mobilization from sediment by establishing an oxidized barrier to diffusion (Jaynes and Carpenter 1986). As oxygen release raises sediment redox potential, precipitation of ferric and manganese oxyhydroxides on or around plant roots occurs (Wium-Andersen and Andersen 1972, Tessenow and Baynes 1975). Under oxidized conditions, ferric and manganese oxyhydroxide complexes adsorb P and other mineral elements (Mortimer 1941, 1942; Chambers 1990) making them less available for diffusion into overlying water.

In the root zone, oxic/anoxic interfaces also provide suitable micro-environments for nitrification and denitrification activity. Denitrification results in the formation of gaseous N_2 and the removal of nitrate from the system under anoxic conditions. Because ammonium oxidizing bacteria require the simultaneous presence of both ammonium and dissolved oxygen, the potential exists for populations of these bacteria to increase the rates of ammonium oxidation to nitrate and nitrite. The latter forms of nitrogen are less favored than ammonium for uptake by aquatic macrophytes (Nichols and Keeney 1976).

Marsh Plants of Interest

Many people are concerned with the intentional and unintentional introduction of non-native species (Mooney and Drake 1986). These species often induce changes in the structure and function of the ecosystems into which they are introduced, dominating the native species that once resided there. Knowledge of sediment chemistry associated with aquatic plants may help explain the present species composition and distribution of native and non-native plant species. For this reason, a native (narrow-leaved cattail, *Typha angustifolia*), an invasive (common reed, *Phragmites australis*), and an exotic (purple loosestrife, *Lythrum salicaria*) plant species were selected in order to examine how they affect sediment chemistry of the Hudson River marsh ecosystem.

Common reed is a perennial reed with thick rhizomes. They are abundant in marshes, seeps, and along rivers around the world. Cattail is a slender plant that grows in coastal and inland marshes (Correll and Correll 1975). In North America, purple loosestrife is a classic example of a non-native species whose distribution and spread has been enhanced by the absence of natural enemies and the disturbance of natural systems, primarily by humans. The plant was introduced in the early nineteenth century both as a contaminant of European ship ballast and as a valued medicinal herb (Stuckey 1980). It now occurs in dense stands throughout the northeastern United States, southeast Canada, the midwest, and in scattered locations in the western United States and southwestern Canada (Malecki et al 1993). Purple loosestrife is listed as a noxious weed in thirteen states, where its importation and distribution is prohibited (Malecki et al 1993). This perennial is responsible for the degradation of wetland systems by replacing native plant species (Stuckey 1980) and thereby eliminating natural foods and cover essential to many wetland wildlife inhabitants.

Methods

Common reed, purple loosestrife and cattail were sampled at the Tivoli Bays

component (Figure 1) of the Hudson River National Estuarine Research Reserve (HRNERR). Percent species composition of each site was determined by sampling (n=3) with a 0.25 m² quadrat. Sediment oxidation-reduction status, organic content, and percent moisture were determined in replicate sediment cores (n=3). Above-ground biomass of macrophytes was determined during August 1995 by random sampling (n=3) with a 0.25 m² quadrat. Below-ground plant material with depth was sampled in each vegetation type by collecting sediment cores with plants (2.75 inch diameter, 6 cm depth). Above- and below-ground plant matter was dried at 60 degrees C until constant weight was attained.

Platinum and calomel (reference) electrodes were used to measure the relative oxidation-reduction status for the top 5 cm of sediment. The electrode was placed directly into the sediment (n=3) for each vegetation type and allowed to equilibrate for five minutes. A value of 244 was added to each measurement in order to adjust for the calomel electrode.

Profiles of porewater nutrients (ammonium, nitrate, and phosphate) were sampled in situ with PVC equilibrators (peepers, Figure 2) using standard methods (Hesslein 1976, Bottomley and Bayley 1984). Dissolved constituents in the sediment diffused from the sediment porewater across the polycarbonate membrane and into the sampling cavities (located every 3.0 cm to a depth of 24 cm). Peepers (n=3 in each vegetation type) were prepared in the laboratory using deoxygenated, deionized water in each sampling cavity, and set at the field sites for approximately one week to allow for equilibration prior to retrieving. Upon retrieval, the peepers were sampled immediately (within minutes) in the field by extracting porewater from the cavities with a syringe and filtered (0.8 um) into 10 ml vials containing 100 ul 5.4 N HCL.

Above-ground plant material (n=6 in each vegetation type) was collected, dried and ground using a 40 um mesh. Nitrogen content was determined with a Carlo-Erba C-N Analyzer. Vegetative content of phosphorus was determined using a method modified by Chambers and Fourqurean (1991). Phosphorus concentrations of acid-digested samples were determined colorimetrically using the molybdate blue method.

Statistical Procedures

Analyses of variance (ANOVA) were performed using SGPL US. Multi-factor statistically significant differences were defined as those for which $p < 0.05$ (Appendix A).

Tivoli Bays

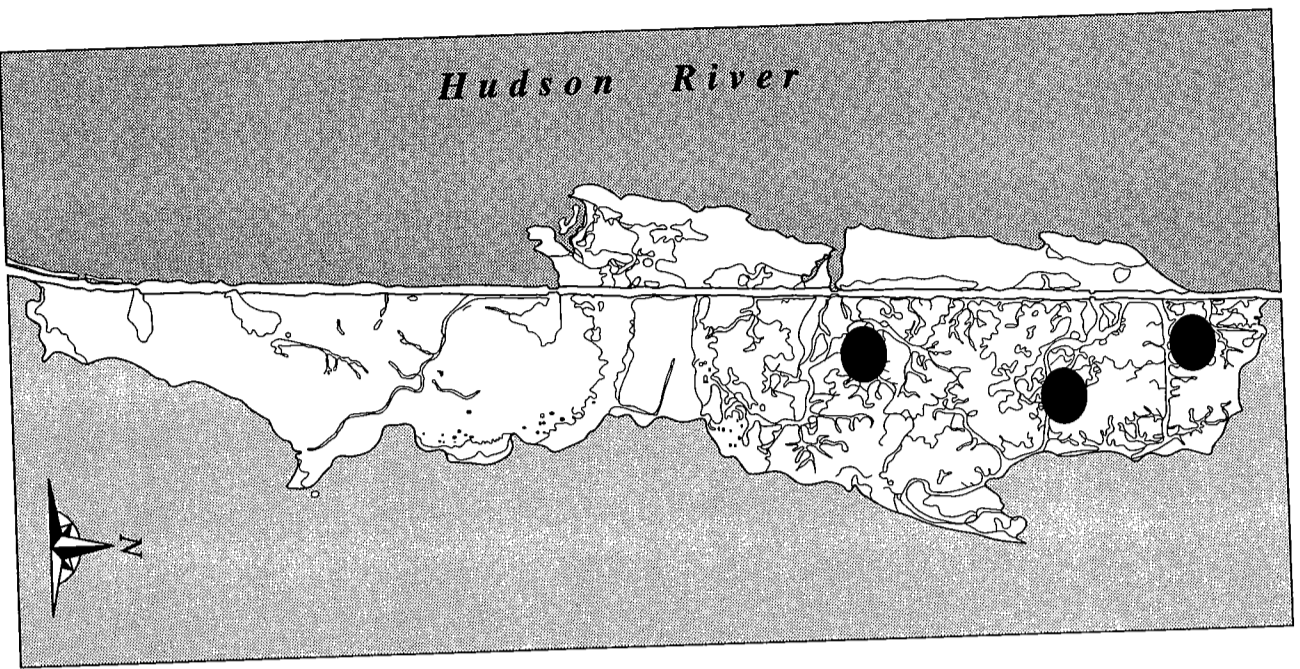


Figure 1. Map of study sites. All three vegetation types (*T. angustifolia*, *P. australis*, and *L. salicaria*) occur at each site.

II-12

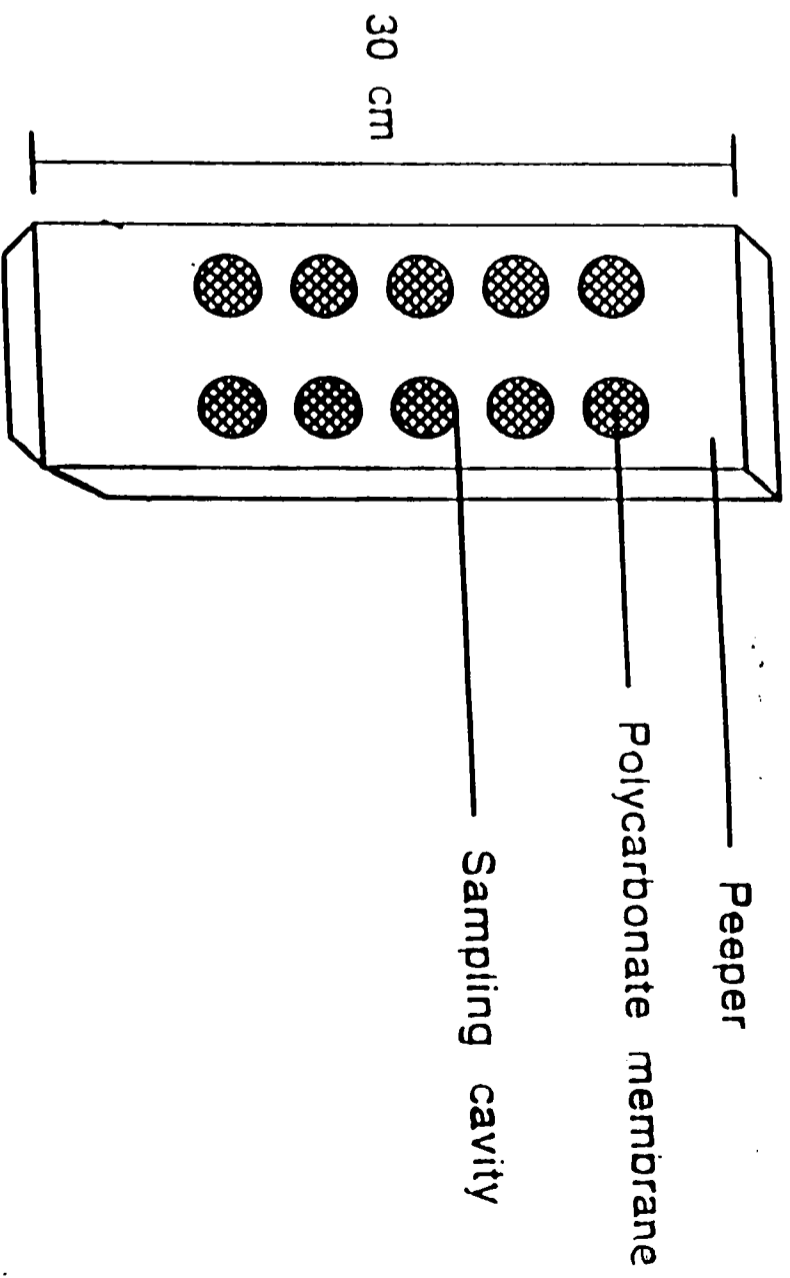


Figure 2. PVC equilibrators (Peepers) used to measure porewater nutrients.

II-13

Results

Sample plots contained at least 70% above ground biomass of target plant species at each site (Figure 3). Common reed had nearly twice as much above- and below-ground biomass as either cattail or purple loosestrife (Table 1). However, we may be underestimating purple loosestrife's below ground biomass because it was very difficult to take cores of their extremely thick, strong roots (some 3 cm wide). Sediment organic matter ($p=0.89$, Figure 4) and moisture levels ($p=0.73$, Figure 5) did not vary statistically significantly among vegetation types. Although statistically insignificant ($p=0.21$), oxidation-reduction status (Figure 6) was higher in common reed ($Eh=79.45 \pm 34.77$) stands than the cattail ($Eh=37.83 \pm 37.97$) or purple loosestrife stands ($Eh=58.65 \pm 43.43$).

Phosphorus concentration was significantly higher ($p<0.05$, Figure 7) in the above-ground plant matter of purple loosestrife (5.88 ± 0.56 mg PO_4/g plant) compared to cattail (3.66 ± 0.20 mg PO_4/g plant) and common reed (4.70 ± 0.21 mg PO_4/g plant).

Nitrogen concentration was significantly higher ($p<0.05$, Figure 7) in the above-ground plant matter of common reed (17.67 ± 1.83 mg N/g plant) compared to cattail (9.11 ± 0.42 mg N/g plant) and purple loosestrife (7.44 ± 0.90 mg N/g plant).

We multiplied the concentration of P and N by the total above-ground biomass of each plant species (per m^2) to determine the total standing stock of nutrients (Figure 7). Total standing stock amounts of N and P were significantly higher ($p<0.05$) in the above-ground plant matter of common reed (N: 17.25 ± 1.82 g/ m^2 ; PO_4 : 4.61 ± 0.20 g/ m^2) compared to cattail (N: 4.65 ± 0.21 g/ m^2 ; PO_4 : 1.87 ± 0.10 g/ m^2) and purple loosestrife (N: 4.71 ± 0.57 g/ m^2 ; PO_4 : 3.73 ± 0.35 g/ m^2).

Porewater ammonium and phosphate values were averaged across depth for each plant at each site because there was no significant ($p>0.05$) depth effect (Figures 8,9). Porewater pools of ammonium in spring were significantly lower ($p<0.05$, Figure 10) in stands of cattail (6.33 ± 1.22 mg N/L) compared to common reed (15.09 ± 1.22 mg N/L) and purple loosestrife (11.32 ± 1.32 mg N/L). In spring, porewater pools of phosphate were significantly lower ($p<0.05$, Figure 11) in stands of exotic purple loosestrife (3.65 ± 0.71 mg PO_4/L) than cattail (4.17 ± 0.52 mg PO_4/L) or common reed (6.51 ± 0.59 mg PO_4/L).

In summer, porewater pools of ammonium and phosphate were significantly lower ($p<0.05$, Figure 10,11) in stands of purple loosestrife (NH_4-N : 0.15 ± 0.02 mg/L; PO_4 : 3.21 ± 0.60 mg/L) with phosphate concentrations only half those of common reed (NH_4-N : 0.88 ± 0.19 mg/L; PO_4 : 6.85 ± 0.50 mg/L) or native cattail (NH_4-N : 0.31 ± 0.10 mg/L; PO_4 : 6.71 ± 0.46 mg/L). There was no detectable amounts of porewater nitrate in sediments associated with any of three plant communities in either May or July.

To assess the seasonal turnover of porewater nutrients due to plant uptake (Figure 12), we divided the amount of total P and N standing stock (nutrient uptake by plants) by the size of the porewater pools of P and N at the beginning of the growing season (May). The following describes how we determined the amount of available porewater N and P (L/200,000 cm^3 soil) in the sediment. We multiplied porosity levels of each soil sample (0.696 g water/ cm^3 wet soil) by 200,000 cm (the total volume of sediment in a m^2 area to 20 cm depth, the active root zone of these plants). We calculated porewater P and N (g) by multiplying porewater concentrations (mg/L) by the amount of porewater available to each plant (L).

Purple loosestrife had a statistically significant higher ($p < 0.05$) seasonal turnover rate of phosphorus (7.34 ± 0.69 times per season) compared to common reed (5.09 ± 0.28 times per season) and cattail (3.22 ± 0.18 times per season). Common reed had a statistically significant higher ($p < 0.05$) turnover rate of nitrogen (8.21 ± 0.87 times per season) compared to cattail (5.27 ± 0.24 times per season) and purple loosestrife (2.99 ± 0.36 times per season).

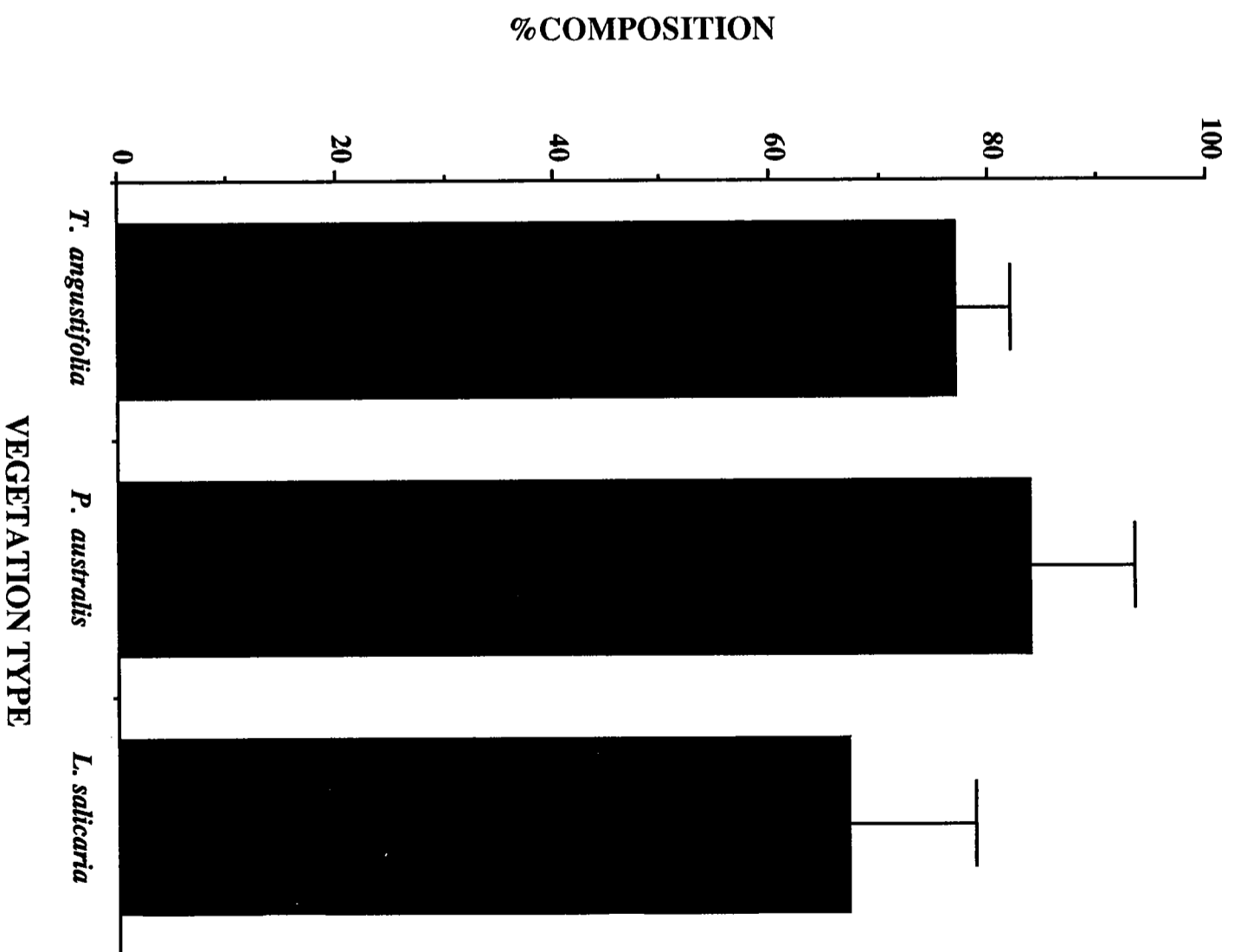


Figure 3. Percent composition of target species at each site (values are means, $n=6$; error bars represent standard error).

Table 1. Above-ground (values are means, n=6) and below-ground (values are means, n=2) biomass of three vegetation types (with standard error).

Plant Type	Above-ground biomass (g/m ²)	p-value	Below-ground biomass (kg/m ² to 6 cm depth)	p-value
<i>T. angustifolia</i>	510 +/- 59.3	0.05	4.71 +/- 1.67	0.16
<i>P. australis</i>	980 +/- 172.4		10.83 +/- 2.20	
<i>L. salicaria</i>	633 +/- 116.6		4.17 +/- 1.88	

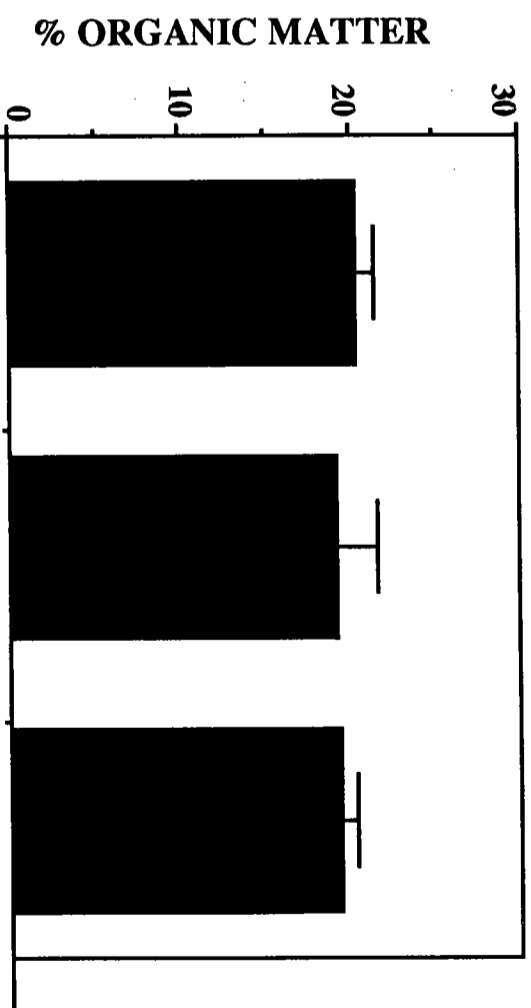


Figure 4. Comparisons of sediment percent organic matter among three vegetation types (values are means; n=16, 16, 14 for *T. angustifolia*, *P. australis* and *L. salicaria* respectively; error bars represent standard error).

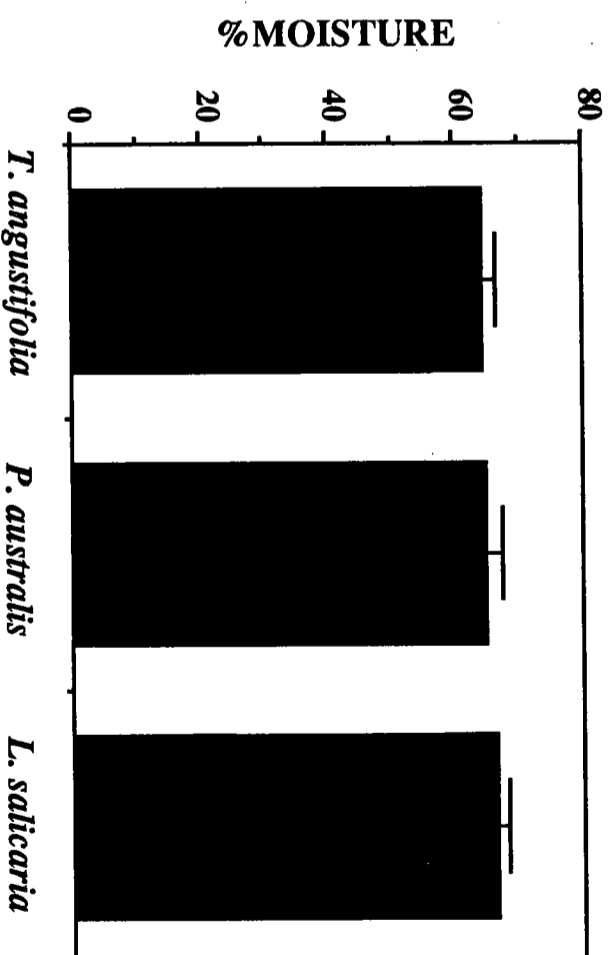


Figure 5. Comparisons of sediment percent moisture among three vegetation types (values are means; n=16, 16, 14 for *T. angustifolia*, *P. australis* and *L. salicaria* respectively; error bars represent standard error).

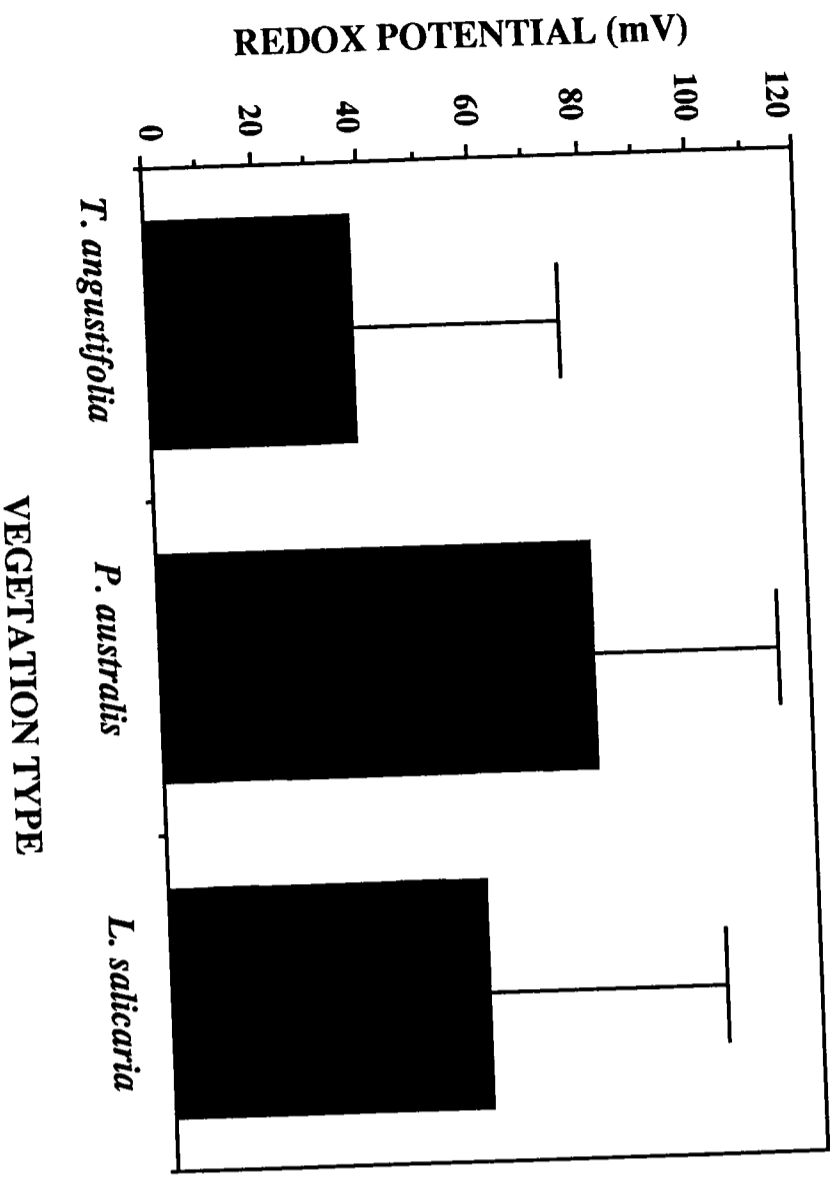


Figure 6. Oxidation-reduction potential of the sediment at 5cm depth (values are means, n=3; error bars represent standard error).

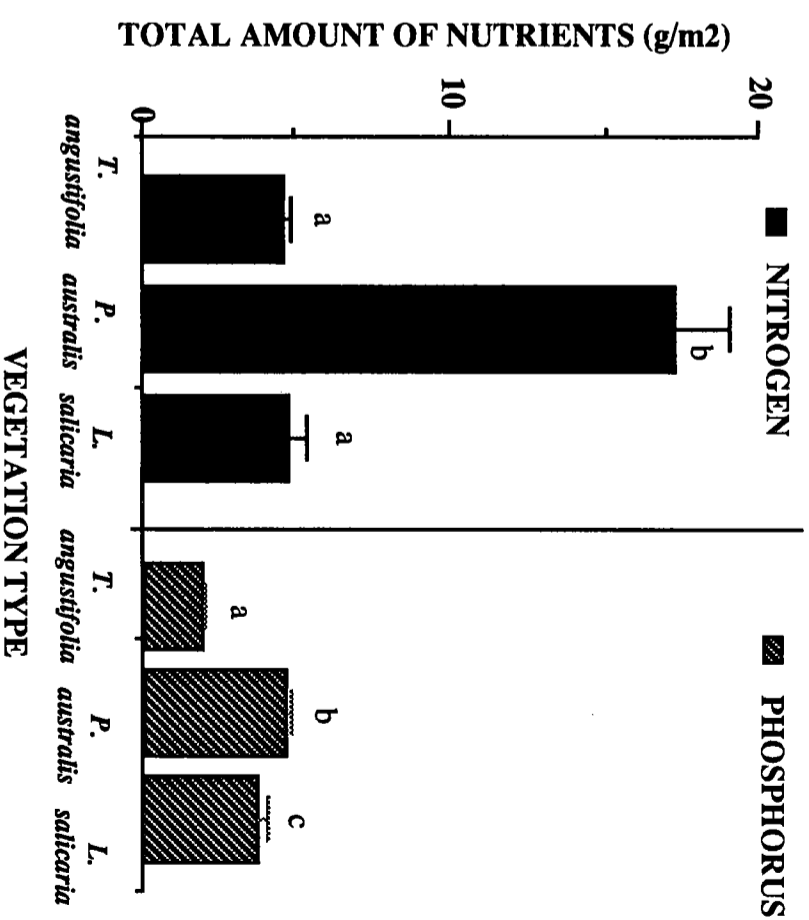
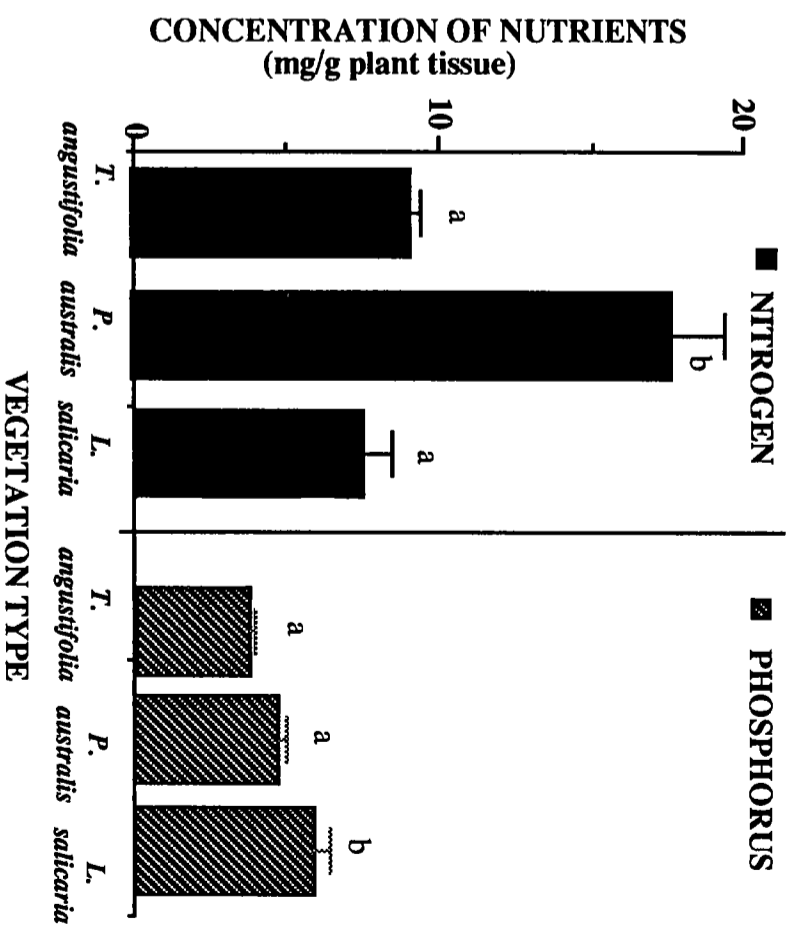


Figure 7. Concentration of nitrogen and phosphorus in above-ground plant tissue and total amount in above-ground plant tissue per m² (values are means, n=6; error bars represent standard error). For each nutrient, bars that share common letter are not statistically significantly different ($p < 0.05$).

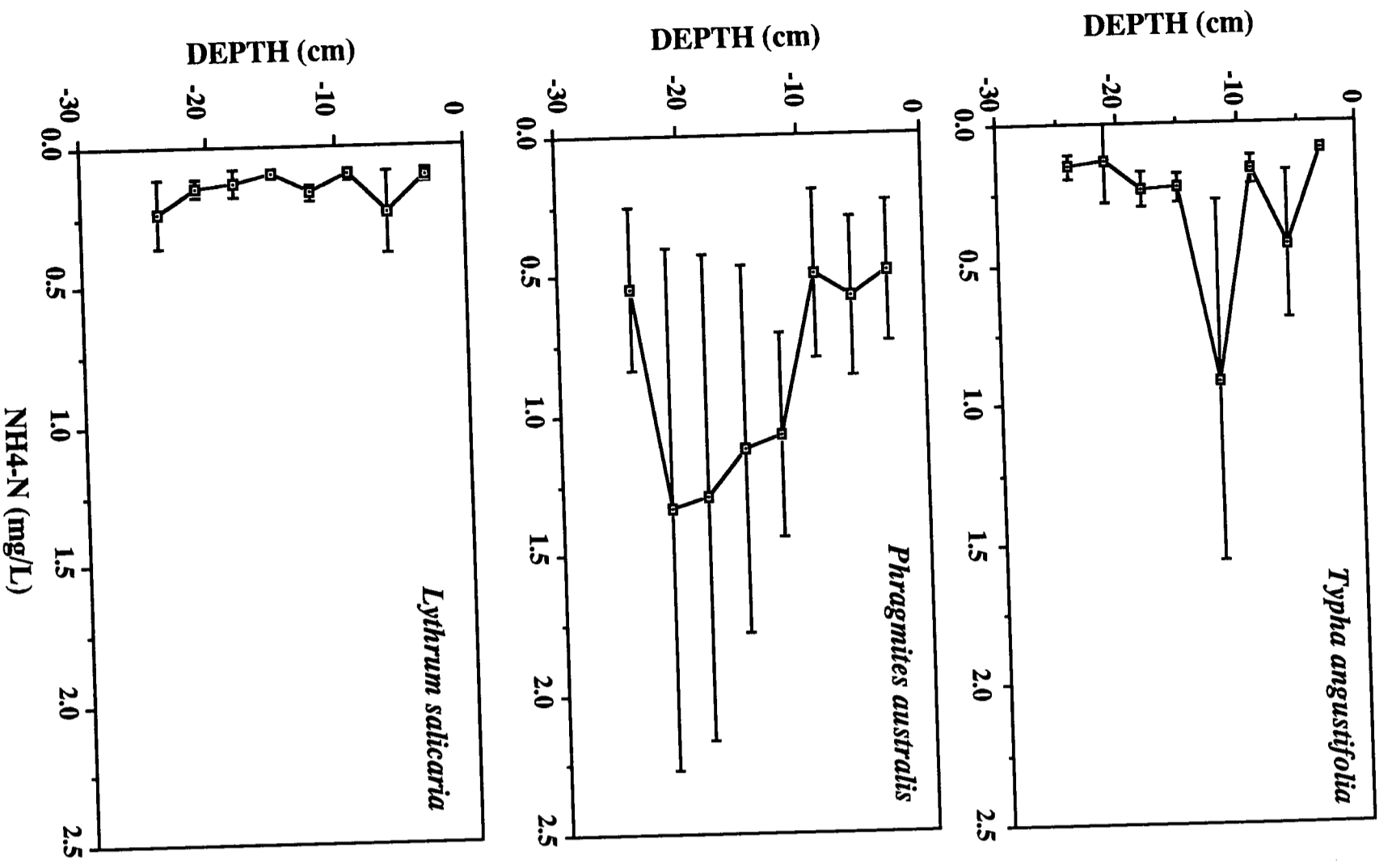


Figure 8. Profile of porewater ammonium in the sediment associated with each vegetation type in summer (values are means, $n=3$; error bars represent standard error).

II-22

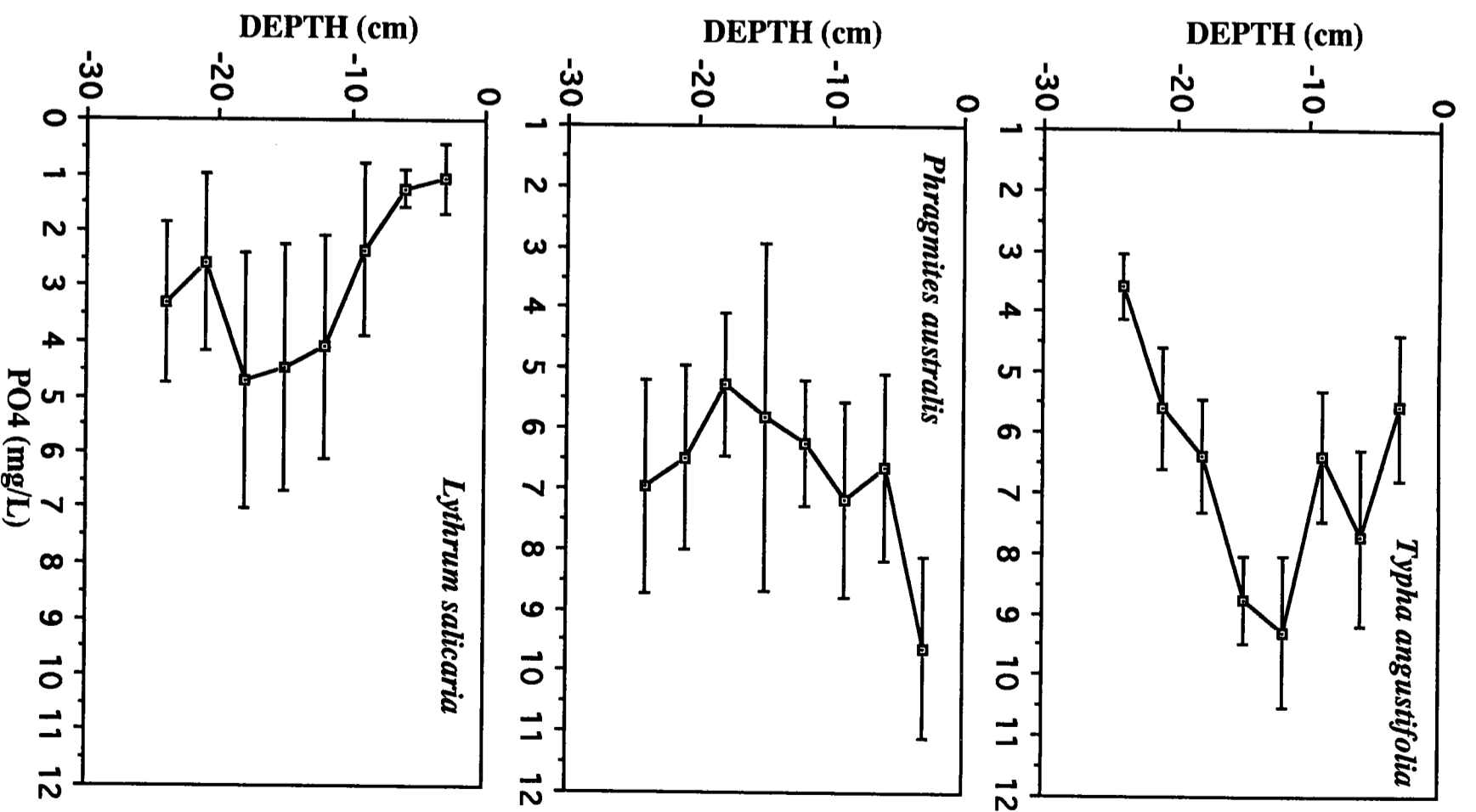


Figure 9. Profile of porewater phosphate in the sediment associated with each vegetation type in summer (values are means, $n=3$; error bars represent standard error).

II-23

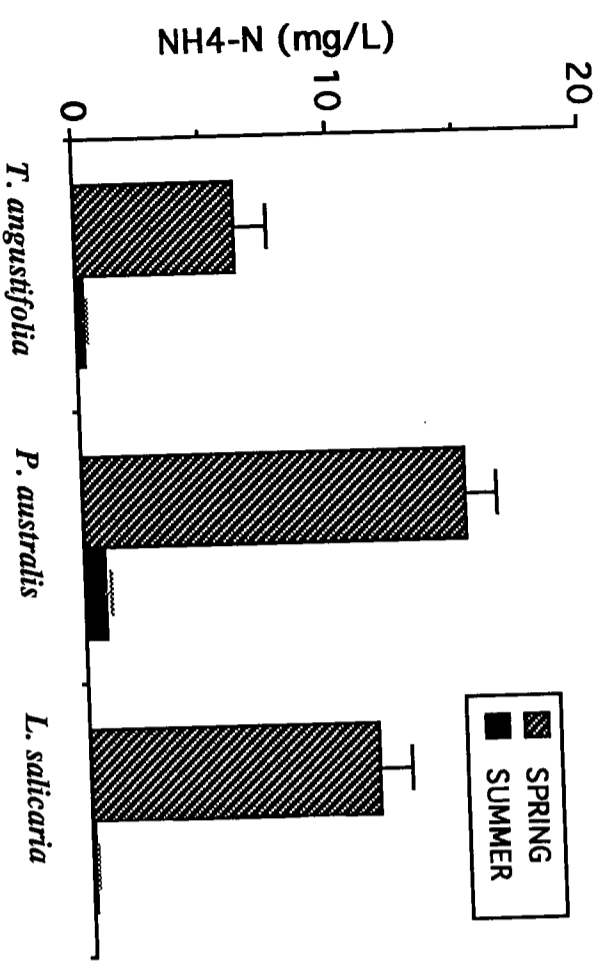


Figure 10. Ammonium in sediment porewater of each vegetation type averaged across depth (Spring: n=24, Summer: n= 22, 31, 29 for *T. angustifolia*, *P. australis*, and *L. salicaria* respectively; error bars represent standard error).

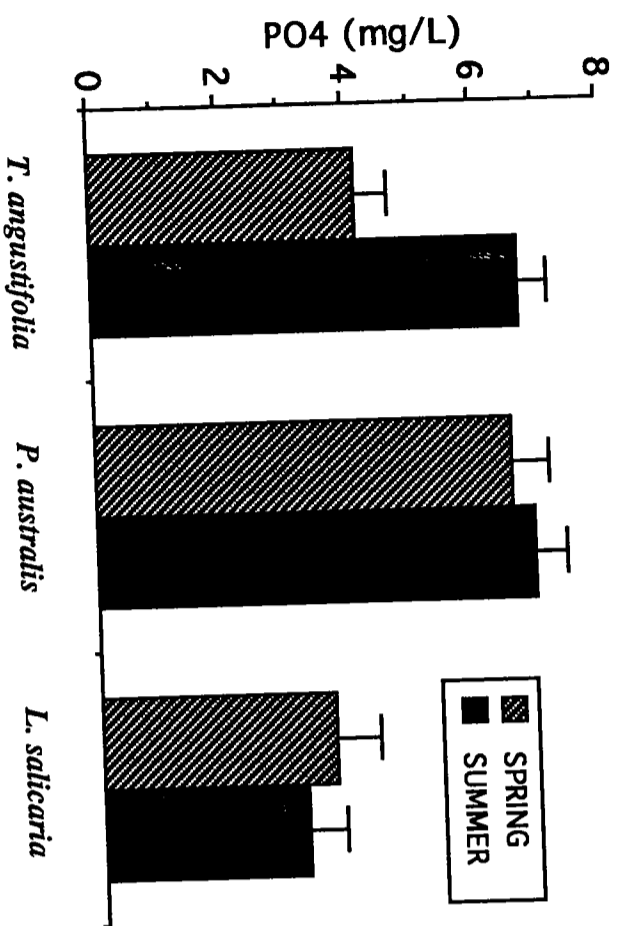


Figure 11. Phosphate in sediment porewater of each vegetation type averaged across depth (Spring: n=23, 20, 20; Summer: n=57, 48, 33 for *T. angustifolia*, *P. australis*, and *L. salicaria* respectively; error bars represent standard error).

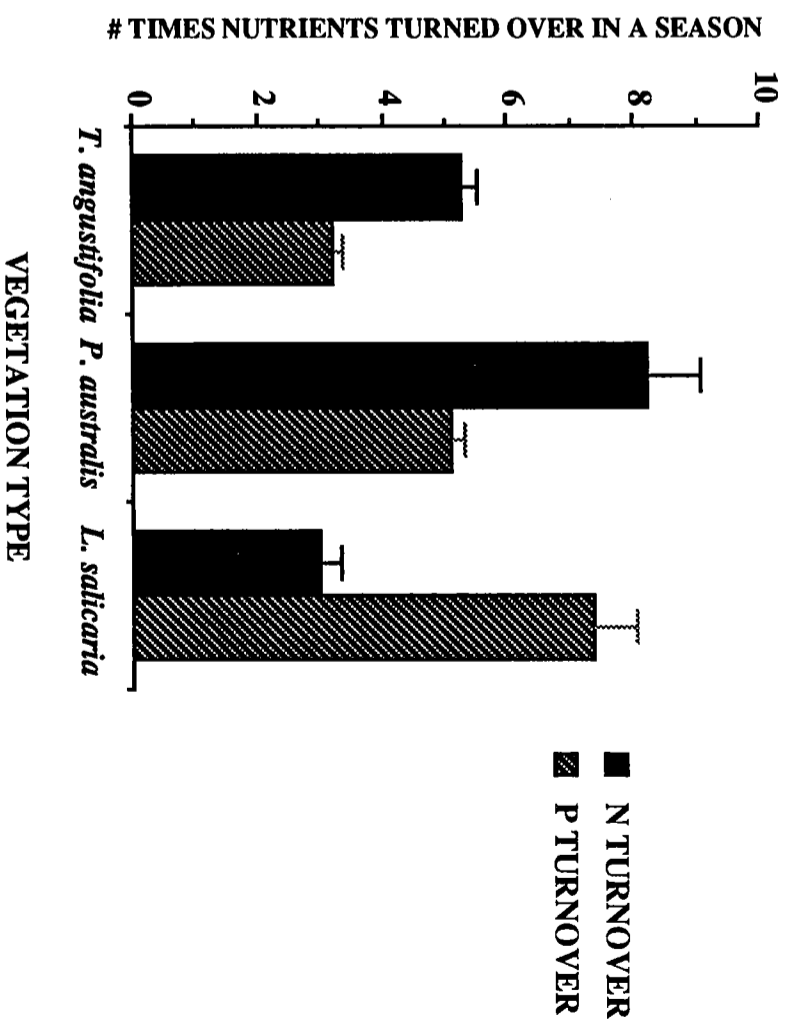


Figure 12. Turnover of porewater nutrients (N and P) over a season (values are means, n=6; error bars represent standard error).

